Hydrology Investigation Comparing Subsequent Collection Sites

Madison Plains High School

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Abstract

This investigation was made in order to observe hydrology trends in the local water network. Working in compliance with the GLOBE program, water was collected and analyzed by high school students each month. The key measurements focused on were alkalinity, pH, temperature, dissolved oxygen, and nitrates. It was hypothesized that each factor followed a pattern that could be interpreted by graphing the changes occurring as water flowed downstream every recording period. Some predictions about their relationships were refuted, and others, confirmed. This research will serve as a basis for future analyses conducted by forthcoming classes.

Research Questions and Hypothesis

The class established the goal of answering, “How do alkalinity, pH, temperature, dissolved oxygen, and nitrates fluctuate downstream and interact with one another?” Because little was known of such tendencies at the time, the students made the following inferences to the best of their ability:

- nitrates and dissolved oxygen are directly correlated
- dissolved oxygen and alkalinity are inversely correlated
- alkalinity and pH have are inversely correlated
- temperature and dissolved oxygen are inversely correlated
- dissolved oxygen and alkalinity are inversely correlated

This was the first hydrology investigation done by students at Madison Plains High School. Being the starting point for an ongoing series of related projects, it was important to familiarize the class with the correct procedures through personal experience. Needless to say, trial and error played a considerable role in teaching the students about proper, scientific research.

Introduction

The Biology II class of Madison Plains High School (39°47.36” N, 83°28.91” W) has begun a Global Learning and Observation to Benefit the Environment (GLOBE) research project to test for hydrology data. Each person in the study had a different lake, stream, or creek in Madison or Fayette County, Ohio in which temperature, pH, dissolved oxygen, nitrate and alkalinity data were collected once a month from September 2012 to February 2013. The location of sites where the data were collected is labeled A-E. Figure 1 shows the location of the sites. The furthest upstream of the sites is labeled as “A”, the furthest downstream is labeled as “E”. The local water network analyzed for hydrology data is called Deer Creek. Its main body is a river which flows southward into a lake created by the construction of a dam, which is located before site E. Note that the amount of water that is allowed through the dam is controlled by the Army Corps of Engineers.

The first data set analyzed was dissolved oxygen (DO), which measures the amount of gaseous oxygen dissolved in an aqueous solution (KY Water Watch 2011). It is found in microscopic air bubbles within the water. The oxygen enters the water by aquatic plants or algae through the process of photosynthesis (Switzerland County High School 2000). DO is necessary for living organisms such as fish as they absorb oxygen through their gills. Temperature of the water can affect the levels of DO present. The colder the water the higher the DO levels will be, and accordingly as the water temperature increases, the DO levels decrease.

Another characteristic of natural water resources analyzed during the investigation was nitrates. A nitrate is a chemical compound composed of nitrogen and oxygen, represented by NO_3^- (Hill, 2011). Nitrates form as a byproduct when bacteria decompose organic materials. The bacteria release ammonia (NH_3^+) into the air as they consume proteins, which later bonds with oxygen molecules in the air to form nitrates (Cleveland, 2000). The oxygen-ammonia compound, ($(NH_3)_2O$), settles in the soil and is carried to the water by precipitation runoff.

Because nitrates can hinder the respiration of aquatic animals, the healthy range for freshwater ecosystems is defined as being less than 1 mg/L. Despite their Nitrates provide nutrients for plants that are necessary for their growth. Without nitrates, plants would be unable to grow and form properly. This would in turn cause the process of photosynthesis to be delayed. This would not only harm the plant, but also affect other water qualities and aquatic organisms (Barbara & Nancy, 2010). Most organisms rely on plants to create oxygen that dissolves in the water. When dissolved oxygen levels begin to deplete, organisms begin to struggle to obtain the oxygen they need to survive.

The pH level is a useful measurement to hydrology investigations because it indicates what types of biological life may exist in or around the freshwater ecosystem. For example, it is beneficial in most instances for a freshwater ecosystem to have a pH ranging from 6.5-8.0. This fluctuation can be seen as algae become inactive in the absence of light. These microscopic plants do not have the ability to produce energy through photosynthesis after sunlight hours, and therefore do not take in as much carbon dioxide. Increasing carbon dioxide concentrations shift nature’s equilibrium toward the positively charged hydronium. This causes the pH level to rise during the night and then lower once again as photosynthesis begins after sunrise, when the microbes take in more carbon dioxide from the water in order to produce energy for survival. Moreover, as the temperatures start to decline in the transition to winter, most algae either die or become dormant, preventing photosynthesis and driving the base pH to a more alkaline range (Bachmann 2011).

However, this may be prevented due to another factor called alkalinity, or the ability for a body of water to maintain pH. This characteristic is a result of both the type of bedrock and sediment carried by the water current. Alkalinity is the measure of a body of water to maintain a consistent range of pH. Alkalinity in a water substance means the solution is capable of buffering acidic solutions with high concentrations of hydrogen ions (Bachmann 2011). If the levels are too high compared to standard, the ecosystem may become unbalanced. Alkalinity in which is obscured adds concerns of excessive acid in the water which is harmful to humans and organisms.

Materials and Methods

Students tested dissolved oxygen, temperature, transparency, pH, alkalinity, and nitrates at individual sites. By using the GLOBE protocols and LaMotte testing kits, students were able to maintain consistency throughout the testing. Students also collected between 11:00AM and 1:00PM Eastern Standard Time. Each test was completed three times, and then the results were averaged and recorded.

When testing Dissolved Oxygen, the water sampling bottle was rinsed out then tightly capped and submerged into the water. The cap was removed which allowed the bottle to fill completely without air bubbles. The cap was placed tightly back on while still submerged then the bottle was brought out of the water. The cap was removed from the bottle and eight drops of

Manganous Sulfate Solution were immediately added along with eight drops of Alkaline Potassium Iodide. The bottle was then capped and mixed by inverting several times and a precipitate formed. After letting the precipitate settle below the shoulder of the bottle 1.0 grams of Sulfamic Acid Powder was added along. The bottle was capped again and mixed until the precipitate and reagent completely dissolved (LaMotte- Code 7414). The procedure ‘fixed’ the dissolved oxygen in the sample.

A titration tube was then filled to the 20 mL line with the fixed sample. The titrator was filled with the Sodium Thiosulfate titrating solution. The fixed sample water should start as pale yellow. Eight drops of the starch indicator solution was added and the sample turned blue. The titrator was inserted again. Titrating was continued until the blue color disappeared and the solution turned colorless. The test result was read directly from the marked increment met by the titrator pump on the barrel. (LaMotte- Code 7414).

When testing alkalinity, students filled the titration tube to the 5 mL line with the water that was collected. One BCG-MR Indicator Tablet was then added and water was swirled until the tablet dissolved causing the solution to turn a blue-green color. The reading titrator was filled with Alkalinity Titration Reagent B. After that, the titrator was inserted into the center hole of the top of the test tube cap. While gently swirling the tube, the titrator was slowly pressed down until the solution changed color from blue-green to purple. After the solution turned purple the test result was read directly from the scale where the large ring on the titrator met the barrel. The results were then recorded as ppm. (LaMotte- Code 4491 -DR).

The pH of any given freshwater ecosystem must be taken regularly, monitored, and maintained. In order for complete accuracy, it should be taken at approximately the same area, at approximately the same time, and by two different types of litmus paper. One measures hydroxide, and the other, hydronium by using strips made especially to recognize each hydrogen ion this allows readings to be more precise. In order to obtain legitimate pH measurements from the local aquatic ecosystems, a specific procedure was followed. Latex gloves were advised in the process. Both types of litmus paper were dipped into the water simultaneously. The strips, kept separate, were then placed aside to dry on a sanitary surface. The two samples had to be placed in a designated spot for its specific hydronium or hydroxide measuring function to prevent misidentification. Through the drying process, the litmus paper had become evaluable. The established pH was recognized by comparing the shades on the litmus paper to its own pH scale standard key. If the acidic strip registered an absence of hydronium, the reading was defaulted to the alkaline strip. Likewise, if the alkaline strip indicated no hydroxide, the acidic strip's value became the licit measurement. In the case of a double renege, the calculation would simply be considered perfectly neutral, a pH of 7.0. The procedure was repeated twice more to get an accurate reading. If one or more measurements had not been within ±1.0 pH units of that average, the entire process was repeated. This procedure was instituted in order to produce valid measurements that best represented the water source.

The temperature of the sites was also tested using an alcohol-filled thermometer. However the same brand of thermometer was not used by every student throughout the entire study. Water temperature was taken on site when the students were collecting sample water for the other tests. Following GLOBE protocol, the thermometer was placed in the water to a depth of 10 cm. After three minutes the thermometer was read without being removed from the water, avoiding any discrepancies. The thermometer was kept in the water for one additional minute and the temperature was re-read. If the student had no change in temperature it would be recorded. If by chance the temperature changed over the course of the one minute period, the student had to hold the thermometer in the water for another minute and repeat this process two additional times and the average was calculated the three measurements.

The transparency or turbidity of the water was additionally tested. In normal testing the tube would be 120 cm tall (LaMotte). A 120 cm tube was not available to the class, so the students used the 11 cm tube for the testing. The turbidity tube was filled to the top to obtain the most accurate results possible. The students then placed the tube over the outline of the turbidity chart. By looking down through the water the students could record if the water was transparent or not. If the target secchi disk symbol was completely visible the water was transparent at 11 cm. If the water was cloudy the students had to pour out a small amount of water until it was transparent and record the depth of the water (GLOBE Protocol). The procedure was repeated two additional times and recorded. The average was calculated and recorded for class data collection.

Nitrates were tested using a LaMotte test kit (LaMotte code 3615). A test tube was filled with 5 mL of the sample water and then 0.5 mL of Mixed Acid Reagent was added. The test tube was capped then mixed. After two minutes, 0.1 g of Nitrate Reducing Reagent was added. The tube was capped and inverted thirty times in one minute, to ensure the solution was thoroughly mixed. The mixed solution then was allowed to sit for 10 minutes. The sample test tube was inserted into the Axial Reader provided in the kit. The test tube's color was matched with a color sample standard to determine the level of Nitrates measured in parts per million (ppm). This process was repeated three times then averaged.

Analysis and Results

Alkalinity tended to follow a positive slope as water flowed downstream. The monthly data values were more consistent for sites closer to the lake which is increasingly larger. At site D, the greatest body by volume, the alkalinity varied little from month to month. After the dam, the alkalinity decreased and tended to vary more over time. (Graph 1)

Nitrates were found to be absent in the majority of collections. Increases occurred in October, December, January, and February. Site D recorded nitrate levels in three instances. In February, four out of five data points reported nitrates. (Graph 2)

Temperature followed the expected pattern, decreasing in the transition from autumn to winter and increasing from winter to spring. January reported the lowest average temperature, and September, the highest. Temperature did not appear to correlate with distance downstream. The greatest drop in temperature occurred between December and January. The only rise in temperature occurred between January and February. (Graphs 3 and 6)

The pH data exhibited an increasingly greater range of values with larger bodies of water. The smallest tributary, site A, reported constant pH for every month. Moving downstream, the data became less consistent as the river grew by volume. Location E, situated on the bank of the dam's discharge, recorded a smaller amount of variation than location D, positioned by the lake backing up to the dam. (Graph 4)

Dissolved Oxygen tended to be greater when temperatures were low. January documented the highest average dissolved oxygen, and October the lowest. The data indicates that the dissolved oxygen decreased until site C, where the levels experience an absolute low during four out of the five monthly periods. The greatest average decrease occurred between site B and site C. The greatest average increase occurred between site D and E. (Graph 5)

Conclusion

A location's distance downstream is the most influential factor that dictates pH, alkalinity, and dissolved oxygen. The sediments that usually contribute to water's alkalinity are limestone sediments, which are required for the lake to maintain pH. As the water flows through the dam, those sediments are prevented from exiting the lake. For this reason, the discharge stream may have a lower alkalinity than its source. (Bachmann 2011).

Not a single site reported nitrates in December. However, in January there was an increase of 0.8 mg/L at site E. February yielded the most nitrates; only one site in the recording period reported a lack of nitrates in their water sample. The overall average for the month was roughly 0.2 mg/L (Graph 2). This occurrence may be due to weather conditions that hinder algal growth. (Graph 3) Algae thrive on nitrates, which can be harmful to an ecosystem if there is an unlimited quantity of nitrates. However, algae will not grow unless higher temperatures and sufficient sunlight are available; nitrates may remain stagnant until the conditions are suitable for algal growth.

The pH data varied more with larger bodies of water. The smallest tributary, site A, reported the same pH level from September through February. Downstream, pH becomes increasingly less stable. This may be due to the increasing volume of water as the tributaries merge together. After the dam, site E records more consistent pH than that before the lake. The pH levels were found to have relationships with both season changes and distance downstream.

From October to January, the dissolved oxygen averages increased steadily as winter brought colder water into the region. As of February, the dissolved oxygen concentration began to decrease and is expected to continue this trend as temperatures rise in transition to winter. From Site A to Site E DO levels follow a decreasing trend but are increased considerably after the dam. This change is likely due to the aeration that occurs as water passes through the passages and gates within the dam. It is believed that because the larger streams are less turbulent, less oxygen from the air is therefore absorbed into the water.

Temperature trends are a result of the Earth’s tilted axis. As the northern hemisphere faces away from the sun, the temperatures decrease in the north until the earth starts to tilt towards the sun, making the temperatures increase. Unsurprisingly, the temperatures continuously decrease throughout the months as they near and enter winter. They decrease until they near and enter into the spring months. In addition, it has been observed that the temperature generally increases as the water flows downstream. This is most likely caused by the greater volumes of water conserving a warmer temperature.

Compared to the climate data for this area, all temperatures from September 2012 to February 2013 were average in terms of climate. However, September had less precipitation than average while October had average amount of precipitation. November, however, was above average in precipitation. January and February were mostly consistent with the available climate data. (Graph 6) While considering the data over the past thirty years, precipitation has not been entirely consistent. The climate data shows moderate rainfall with the exception of an increase in the beginning of November 1985, July 1992, January 2005, June 2008 (The Weather Warehouse, n.d.).

Discussion

In the future, water collection should be made more consistently. Because of limited resources, equipment had to be shared among the students. The constant exchange of equipment had to be recorded each month, which caused notable problems with organization. Having an assigned kit for each data site would be advantageous in solving this issue. Moreover, the month-long collection time window proved to be excessively open to variables. A designated week or weekend for data collection would help to prevent discrepancies in the results.

Finally, students should focus on a single body and its tributaries. During the investigation, the water collection sites were chosen according to the students' convenience. Many collections were proven to be unrelated to the other data and were to be omitted during the interpreting process. By strategically choosing subsequent collection points, a better interpretation of data trends could be made.

Acknowledgments

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Conservation, assisted in protocols for collection and interpretation of data. Bonnie Maki and Ranger Will, who work with the Army Corp of Engineers, were available to give our class a tour of the Deer Creek Dam and assist in the understanding of the importance of our hydrology data. Mr. Connick and Mrs. Johnson are teachers at Mahopac High School, in New York, who have been additional resources in collaborating with their students in understanding our data.

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Appendices

Figure 1 Map of Collection Sites

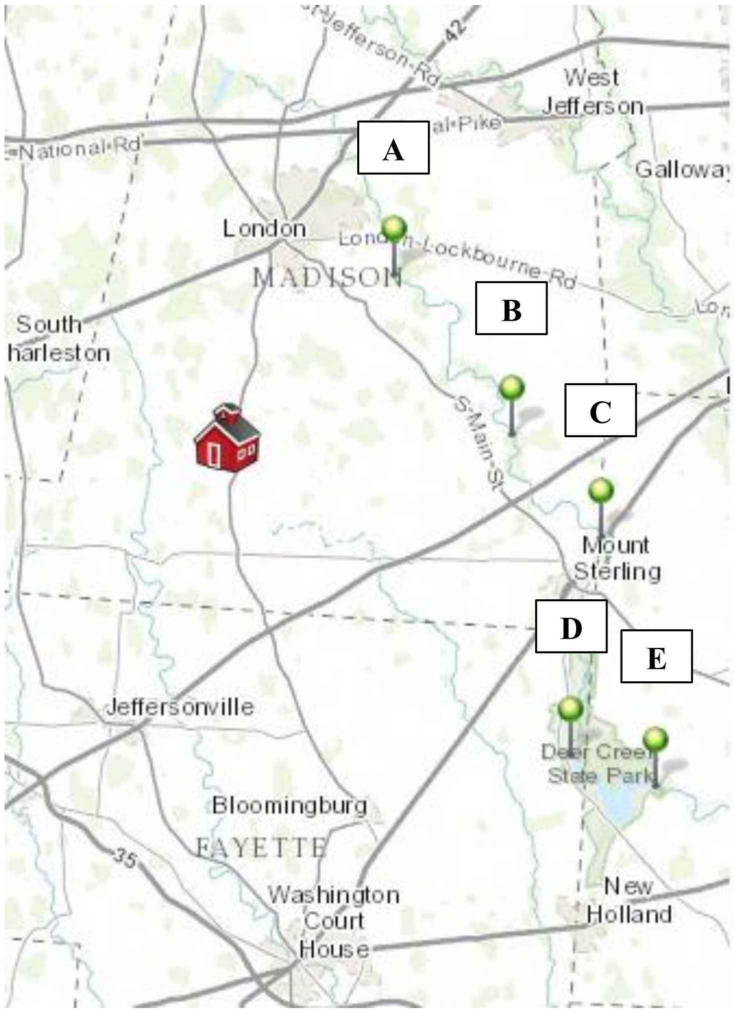
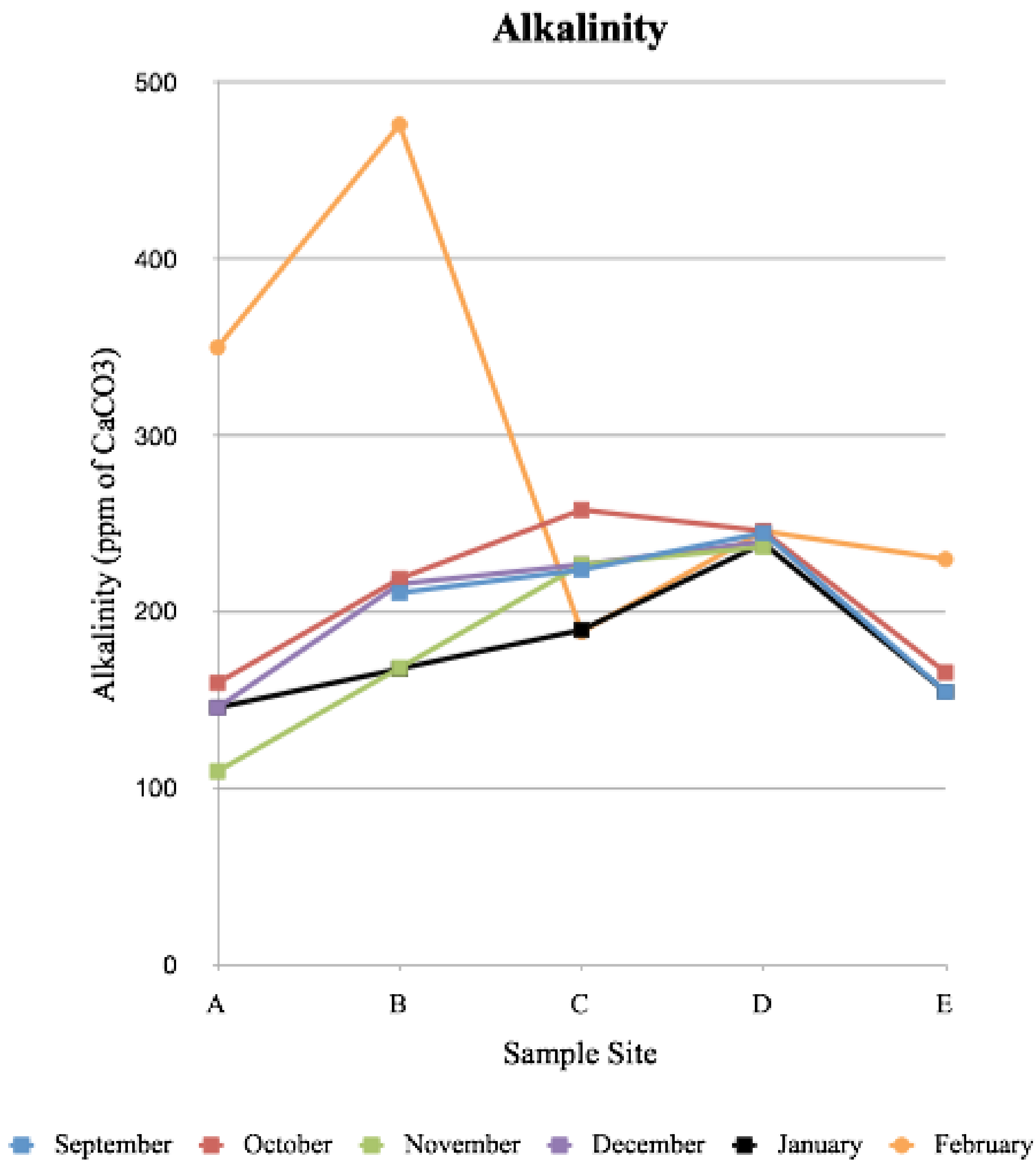


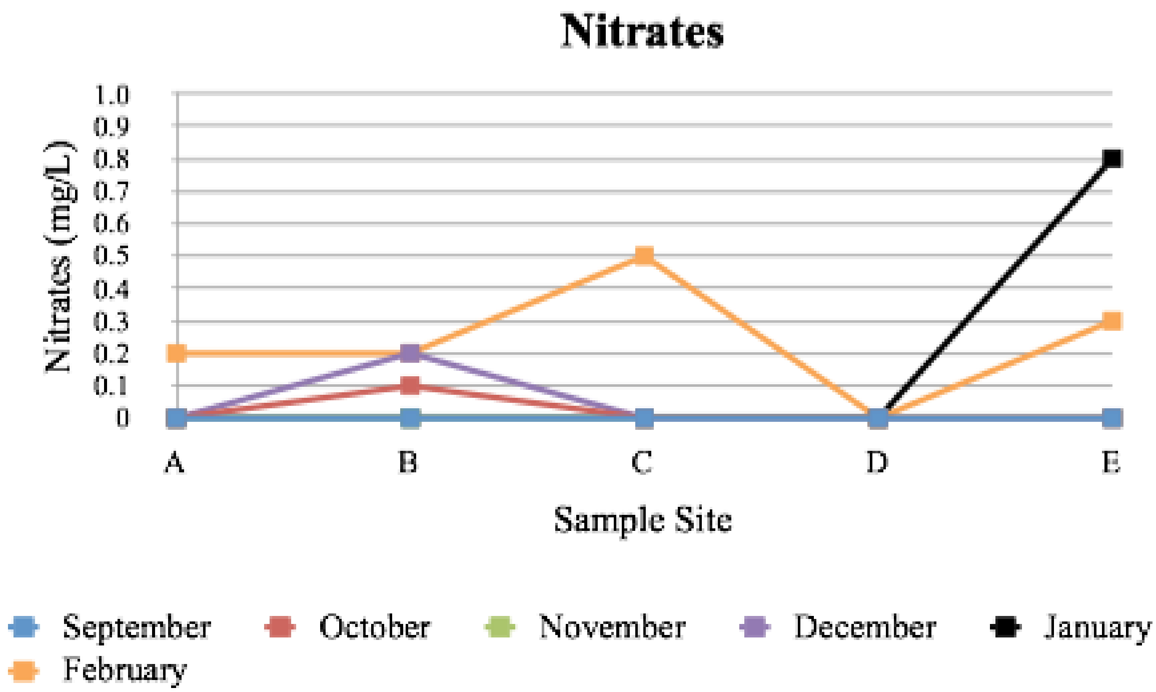
Table 1. GLOBE Hydrology Data Collection Sites

Site Name	Name of Body of Water	GPS Coordinates	County
A	Madison Lake	39°52’15.14”N 83°22’46.65”W	Madison
B	Deer Creek	39°47’18.76”N 83°18’7.44”W	Madison
C	Deer Creek Tributary	39°43’52.98”N 83°15’47.54”W	Madison
D	Deer Creek Lake	39°39’52.65”N 83°16’5.47”W	Fayette
E	Deer Creek	39°37’11”N 83°12’43”W	Pickaway

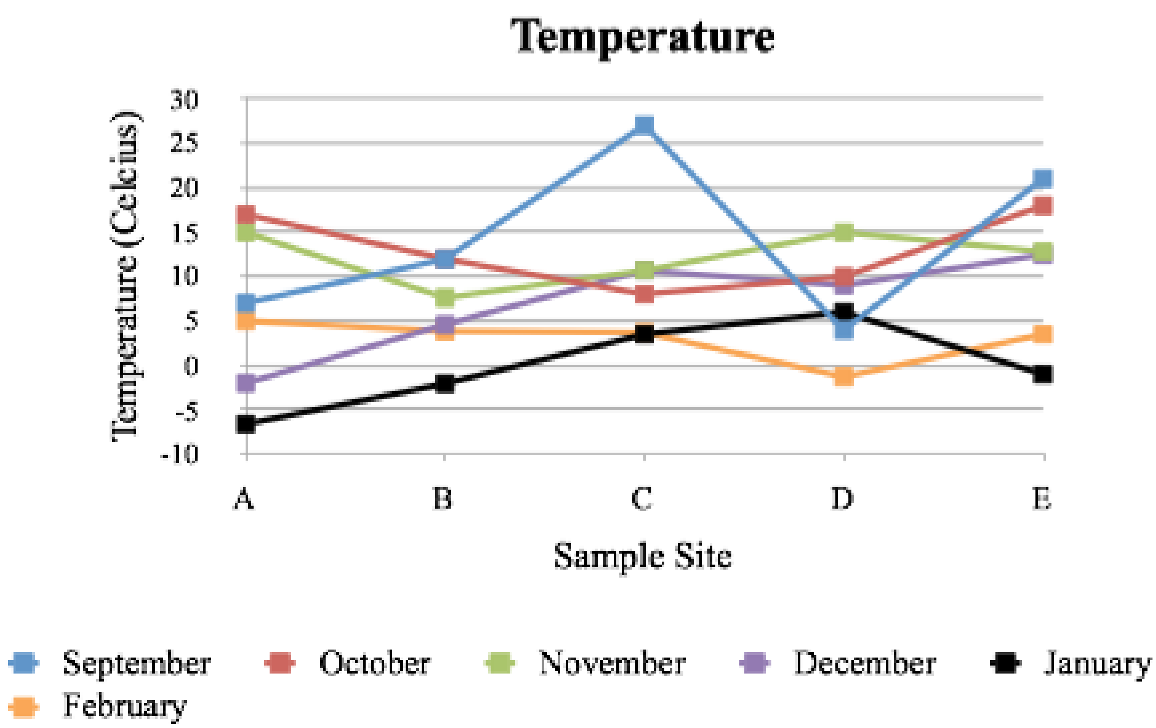
Graph 1


Alkalinity
500
400
300
200
100
0
Alkalinity (ppm of CaCO3)
A
B
C
D
E
Sample Site
September
October
November
December
January
February

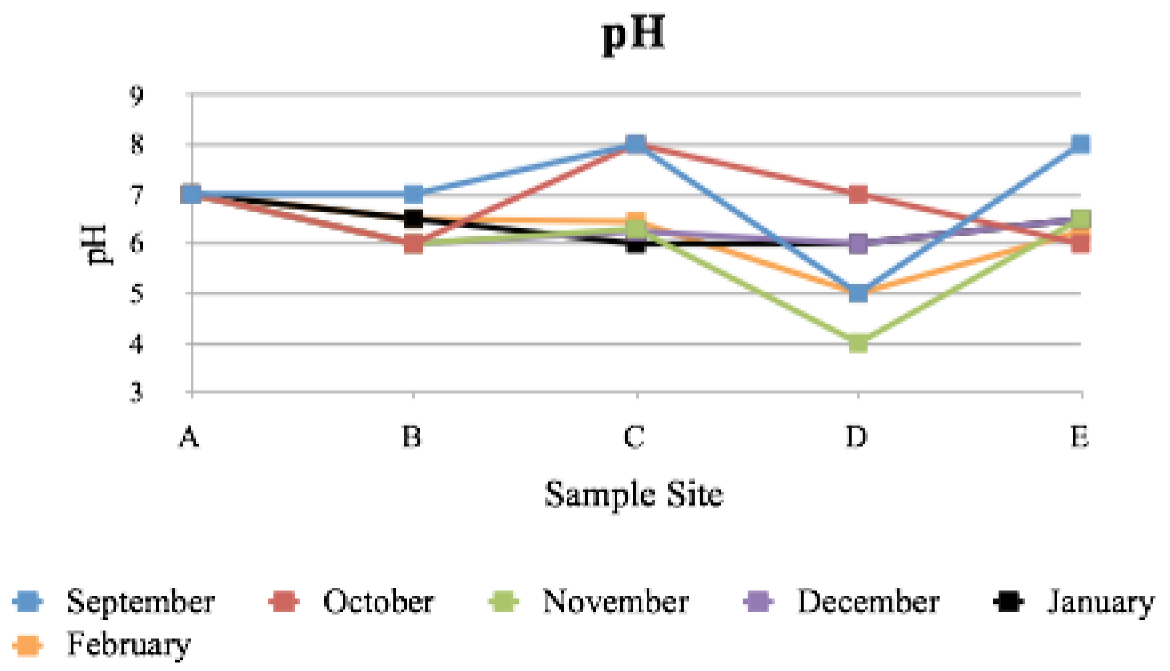
Graph 2



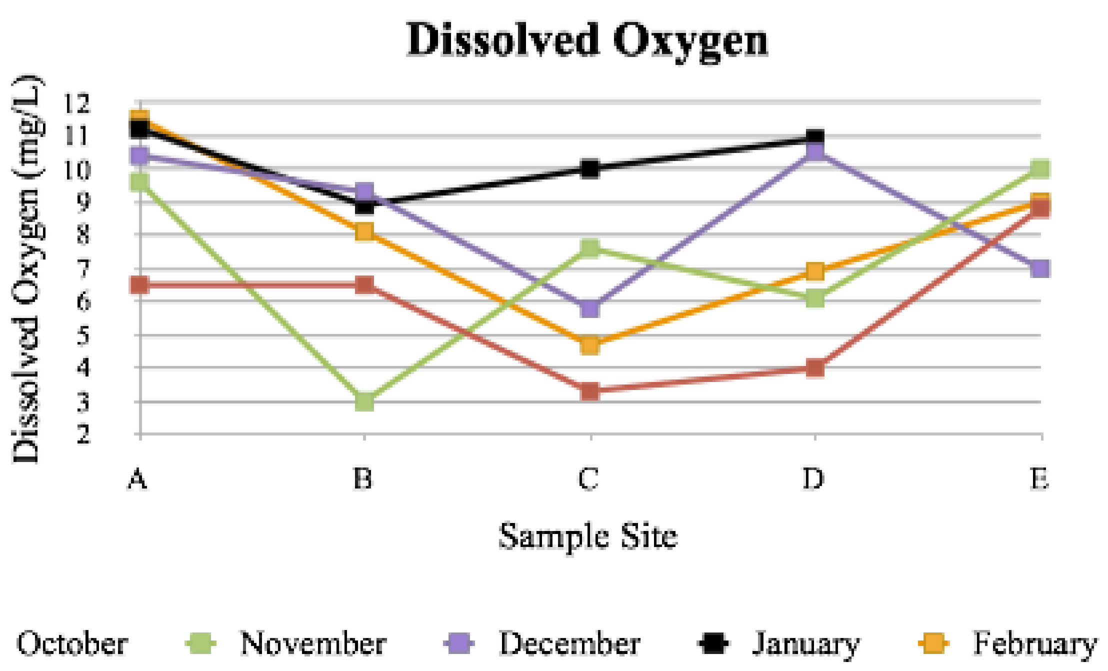
Graph 3



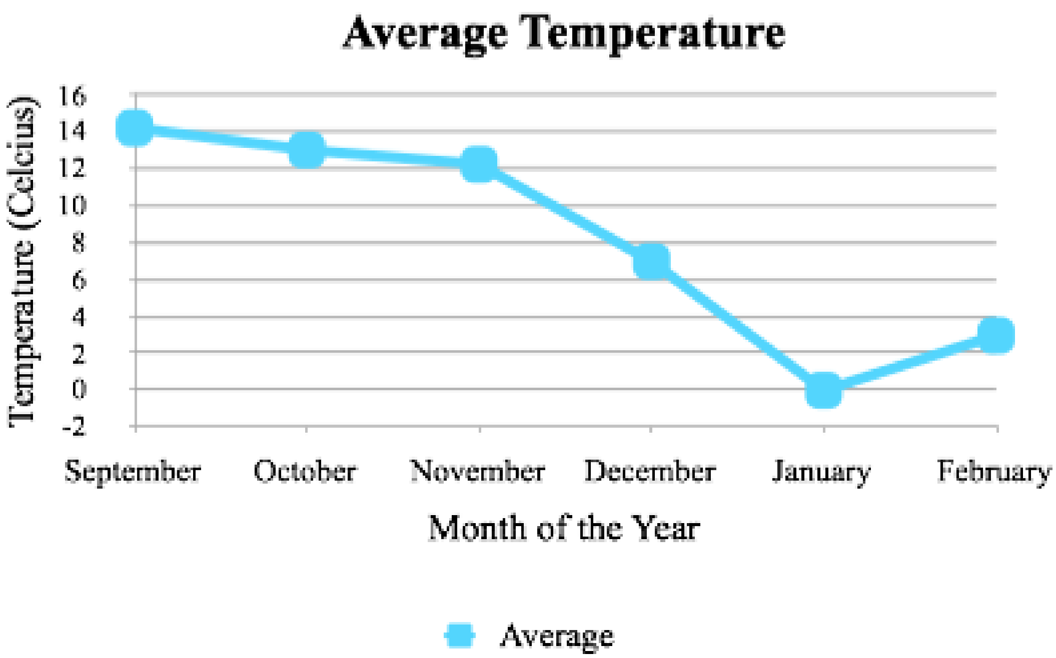
Graph 4



Graph 5



Graph 6


Average Temperature
Temperature (Celcius)
16
14
12
10
8
6
4
2
0
-2
September
October
November
December
January
February
Month of the Year
Average